Title: Guanotrophication by aquatic avifauna on the dynamics of freshwater ecosystem of Ballavpur, India: a modelling approach

Name of the Research Scholar: Sagar Adhurya

Name of the supervisor: Prof. Santanu Ray

Date of Regestration: 28 November 2016

Keywords: Eutrophication, Waterbird, Lake, Biogeochemical Cycle, Dynamic Model

Introduction

Freshwater lakes throughout the world are nowadays threatened by climate change and eutrophication. The crisis of drinking water and disease outbreak resulting from poor water quality has become a global issue for policymakers. In addition to rainfall, anthropogenic (fertilizer, drainage etc.) and biotic (excreta of different animals, dead materials etc.) input are sources of nutrient to water bodies. Many freshwater lakes throughout the globe support a huge number of waterbird congregations. Nutrients from waterbird droppings may serve as an important source of nutrients to those freshwater lakes. '*Guanotrophication'* is a popular term for the nutrient enrichment of water bodies by bird droppings. According to previous studies, congregation of huge number of waterbird in water bodies like lakes for long period may have undesirable effect on water quality through destruction of wetland vegetation (Kerbes et al., 1990), reduction in water quality (Hahn et al., 2008; Manny et al., 1994), increase of heavy metal concentration (Mathis and Kevern, 1975), increase of coliform bacteria (Alderisio and DeLuca, 1999) and increase of water hardness (Chatterjee et al., 2017; Roy et al., 2011). Degraded water quality also may result in a disease outbreak in waterbirds (Friend, 2006; Wobeser, 1997).

The term "waterbird" or "aquatic avifauna" refers to cormorants, ducks, grebes, moorhen, waterhen, jacana etc., which feeds and roosts on the waterbody. Waterbird can modulate the nutrient dynamics of the waterbody in two ways: (i) by changing the form of nutrient in the waterbody (nutrient cycling), (ii) by bringing nutrient from another area to waterbody (external nutrient loading).

Bird droppings consist mainly of undigested materials and excretory materials – uric acid. Most of the faecal matter along with uric acid settles down in the water. After gradual decomposition by decomposer the nutrient in the faecal matter released as bioavailable forms

of nitrogen and phosphorus, e.g. ammonium, nitrate, phosphate etc. Primary productivity of most of the freshwater lakes in the world is limited by phosphorus (Wetzel, 2001). Phosphorus-rich waterbird droppings promote the eutrophication of lakes by providing phosphorus subsidy. But, waterbird driven water quality degradation of the lake depends on the hydraulic retention time of the lake.

Background of the study

The effect of bird-droppings on water quality remains an important area of research for last five decades. Preliminary studies in this aspect were concerned about seabirds. Studies about the effect of waterbird-use of the freshwater lake have been done on different aspects. These are discussed below:

1. **Estimation of waterbird driven nutrient loading:** Direct estimation of nutrient loading by waterbirds was not possible till date. In all cases, it was extrapolated from nutrient content in droppings, defecation rate and the number of waterfowl residing in the lake.
    a. Bédard et al. (1980) took the pioneering approach in this field by calculating the nutrient loading from gulls from the extrapolation of cage bird data.
    b. Gremillion and Malone (1986) added allometric relationship and duration of a day waterfowls spent on the lake with the previous model.
    c. Post et al. (1998) took bioenergetics approach for estimating daily energy requirement of birds and estimated the nutrient loading according to it. They also incorporated gut passage time of food to determine in which places the faeces is dropped.
    d. Hahn et al. (2008, 2007) further improved the bioenergetic model and proposed models for nutrient loading estimation by herbivorous and carnivorous waterfowl respectively.
2. **Comparison between inflow and outflow water sample of a waterfowl refuge:** The concentration of the nitrogenous compound and available phosphorus was higher in the outflow water sample (Brandvold et al., 1976; Olson et al., 2005). Olson et al. (2005) further found that primary productivity of the inlet was limited by both N and P, but outlet was only limited by N. This indicates the importance of P subsidy by waterfowl in the lake.

3. **Comparison between high and low waterfowl-use pond:** It was found that waterfowl density is positively correlated with the phosphorus concentration in the lake (Harris et al., 1981; Hoyer and Canfield, 1994).
4. **Water quality indicator monitoring:** Some workers compared the changes in water quality indicators (hardness, alkalinity, salinity, DO, nitrate, phosphate etc.) with bird abundances (Chatterjee et al., 2017; Roy et al., 2011).
5. **Process-based ecological modelling study:** Oliver and Legovic (1988) build a process based dynamic model on the effect of wading bird guano derived phosphorus on a marshland ecosystem and found that waders have a considerable impact on wetland ecosystem.

Gaps in knowledge

It was found that allochthonous nutrient input by waterbirds may contribute to eutrophication. But till date, no studies have been done to answer how waterbirds derived nutrient contribute to eutrophication. Research also required for understanding the impact of birds dropping on lake trophic chain.

Objectives

The objectives of the present study are as follows-

- Conceptualization of the ways of the transformation of different forms of nitrogen and phosphorus and their contribution to the grazing food chain.
- Experimental determination of different forms of nitrogen and phosphorus present in the water column and sediment, the rate of conversion between these forms and quantification of nutrient input by waterbirds and from other sources.
- Estimation of different rate parameters such as respiration rate, grazing rate, mortality rate etc. for phytoplankton and zooplankton.
- Development of the models for nitrogen and phosphorus to know the effect of waterbird droppings on freshwater ecosystem dynamics and finding the sensitive parameters in the models.
- Predicting the dynamics of the nutrients in the lakes and its effect on grazing food chain.
- Study of the response of state variables to increase and decrease of major forcing functions (guano and anthropogenic input).

Probable methodology

1. **Selection of study site:** Two aquatic bodies were planned to consider for this study: (i) with high winter avian congregation and (ii) with negligible avian aggregation with similar kind of trophic state and anthropogenic disturbance in both sites. So that, the impact of aquatic avifauna on the freshwater system can be depicted.
2. **Determination of state variables:** According to the research question, state variables of the process-based dynamic model will be determined.
3. **Construction of adjacency matrix:** An adjacency matrix depicting the relationship among the state variables will be constructed from available literature.
4. **Development of the conceptual model:** A conceptual model will be developed with the help of the adjacency matrix, available literature and field observations. Then, it will be possible to determine the state variables, forcing functions, parameters and process required for the model. A probable conceptual model is presented in Fig. 1,2.
5. **Data collection:** Data will be collected for all the state variables, forcing functions and parameters as determined in the conceptual model either from the field or experimentally or from available literature whichever possible/applicable for two years. The nutrient input from waterbird dropping will be extrapolated from bird count data using empirical formula.
6. **Mathematical formulation of the process:** Then, the mathematical relationships will be established between the aforesaid modelling elements for each of the processes.
7. **Model verification:** In this crucial step the model will be checked for its internal logic, behaviour and units.
8. **Sensitivity analysis:** In this step, the most sensitive parameters or forcing function to the state variables of the greatest interest of the model will be measured. It is carried out by changing the value of aforesaid modelling elements and the measurement of corresponding changes to the state variables. This step is vital to distinguish between high leverage parameters/forcing function and the low leverage parameters/forcing function, whose values have the significant and minimal impact on the ecosystem respectively.
9. **Calibration:** The best accordance between the simulated and observed data by variation of some selected parameters will be done following the process of calibration.

10. **Validation:** Lastly, the model will be validated using a different dataset which was not used for the construction of the model.

Step 7, 8, 9 and 10 are not rigid step, rather these are an iterative way to construct the model most scientifically and better improvement for future prediction.

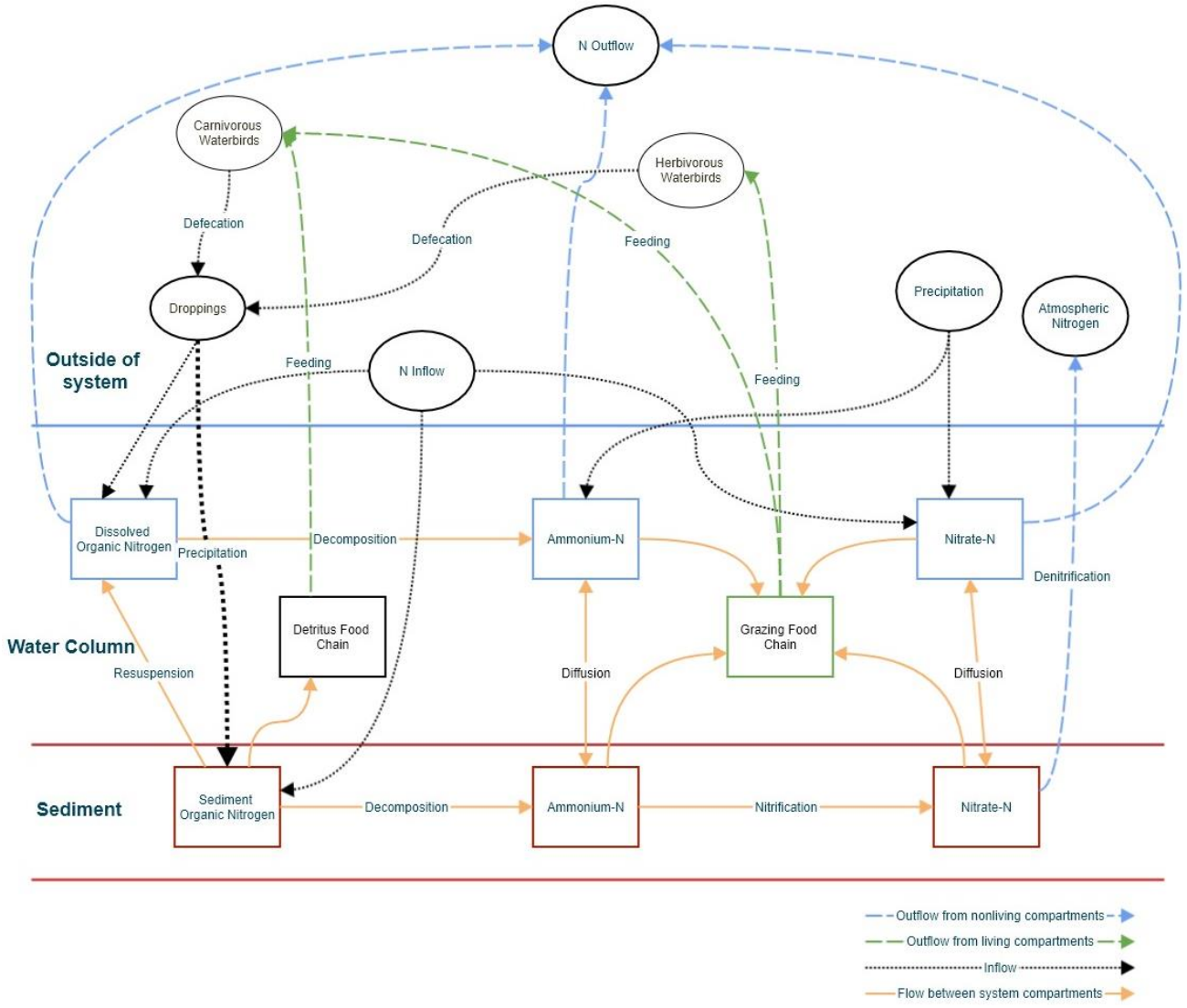

Figure 1: Possible pathway of nitrogen cycling in lake ecosystem incorporating waterfowl dropping

Conclusion

So far, it was known that waterbird-use of freshwater lakes may contribute to eutrophication. As a probable outcome of this research, it will be possible to understand how waterbirds actually contribute to eutrophication. In addition, the relative importance of waterbird-derived nutrient and anthropogenic input for water quality degradation can also be understood. From the model, it will be possible to know that control of which control functions may mitigate

the water quality problem. It will be also possible to understand theoretically that how the overproduction can be utilized in an economical manner. Finally, application of a good ecological model will be useful for sustainable lake management, which in turn will sustain biodiversity of the lake and good water quality for long period.

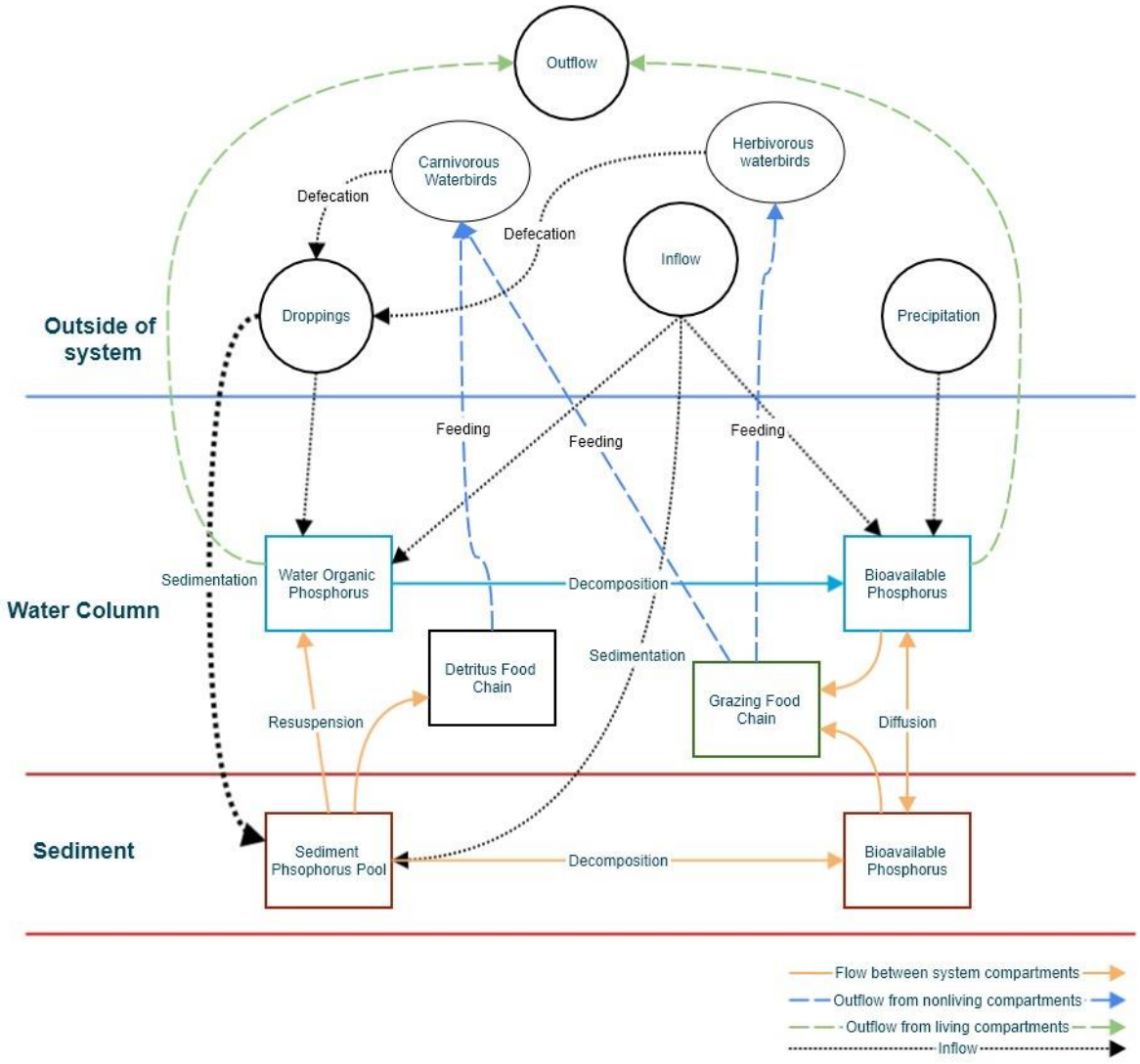

Figure 2: Possible pathway of phosphorus cycling in lake ecosystem incorporating waterfowl dropping.

References

Alderisio, K.A., DeLuca, N., 1999. Seasonal enumeration of fecal coliform bacteria from the feces of ring-billed gulls (*Larus delawarensis*) and Canada geese (*Branta canadensis*). Appl. Environ. Microbiol. 65, 5628–30.

Bédard, J., Therriault, J.C., Bérubé, J., 1980. Assessment of the importance of nutrient recycling by seabirds in the St. Lawrence Estuary. Can. J. Fish. Aquat. Sci. 37, 583–588.

Brandvold, D.K., Popp, C.J., Brierley, J.A., 1976. Waterfowl refuge effect on water quality: II. Chemical and physical parameters. Water Pollut. Control Fed. 48, 680–687.

Chatterjee, A., Adhikari, S., Mukhopadhyay, S.K., 2017. Effects of Waterbird Colonization on Limnochemical Features of a Natural Wetland on Buxa Tiger Reserve, India, During Wintering Period. Wetlands 37, 177–190.

Douglas Oliver, J., Legović, T., 1988. Okefenokee marshland before, during and after nutrient enrichment by a bird rookery. Ecol. Modell. 43, 195–223.

Friend, M., 2006. Evolving changes in diseases of Waterbirds, in: Boere, G.C., Galbraith, C.A., Stroud, D.A. (Eds.), Waterbirds around the World : A Global Overview of the Conservation, Management and Research of the World's Waterbird Flyways. The Stationery Office Limited, Edinberg, UK, pp. 412–417.

Gremillion, P.T., Malone, R.F., 1986. Waterfowl Waste As a Source of Nutrient Enrichment in Two Urban Hypereutrophic Lakes. Lake Reserv. Manag. 2, 319–322.

Hahn, S., Bauer, S., Klaassen, M., 2008. Quantification of allochthonous nutrient input into freshwater bodies by herbivorous waterbirds. Freshw. Biol. 53, 181–193.

Hahn, S., Bauer, S., Klaassen, M., 2007. Estimating the contribution of carnivorous waterbirds to nutrient loading in freshwater habitats. Freshw. Biol. 52, 2421–2433.

Harris, H., Ladowski, J., Donald, J., 1981. Water-Quality Problems and Management of an Urban Waterfowl Sanctuary. J. Wildl. Manage. 45, 501–507.

Hoyer, M. V, Canfield, D.E., 1994. Bird abundance and species richness on Florida lakes : influence of trophic status , lake morphology , and aquatic macrophytes. Hydrobiologia 279, 107–119.

Kerbes, R.H., Kotanen, P.M., Jefferies, R.L., 1990. Destruction of wetland habitats by Lesser Snow Geese: a keystone species on the West Coast of Hudson Bay. J. Appl. Ecol. 27, 242–258.

Manny, B.A., Johnson, W.C., Wetzel, R.G., 1994. Nutrient additions by waterfowl to lakes and reservoirs: predicting their effects on productivity and water quality. Hydrobiologia 279, 121–132.

Mathis, B.J., Kevern, N.R., 1975. Distribution of mercury, cadmium, lead and thallium in a eutrophic lake. Hydrobiologia 46, 207–222.

Olson, M.H., Hage, M.M., Binkley, M.D., Binder, J.R., 2005. Impact of migratory snow geese on nitrogen and phosphorus dynamics in a freshwater reservoir. Freshw. Biol. 50, 882–890.

Post, D.M., Taylor, J.P., Kitchell, J.F., Olson, M.H., Schindler, D.E., Herwig, B.R., 1998. The Role of Migratory Waterfowl as Nutrient Vectors in a Managed Wetland. Conserv. Biol. 12, 910–920.

Roy, U.S., Roy Goswami, A., Aich, A., Mukhopadhyay, S.K., 2011. Changes in densities of waterbird species in Santragachi Lake, India: Potential effects on limnochemical variables. Zool. Stud. 50, 76–84.

Wetzel, R.G., 2001. Limnology: Lake and Reservoir Ecosystem. Academic Press, California.

Wobeser, G.A., 1997. Diseases of Wild Waterfowl, 2nd ed. Springer US, Boston, MA.